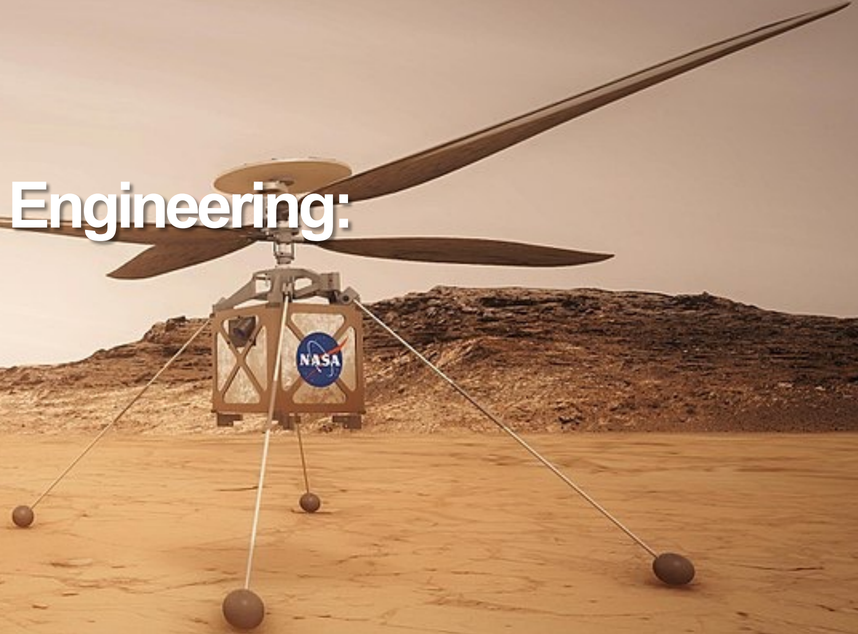
Jet Propulsion Laboratory
California Institute of Technology

New Technologies

Mars Helicopter Telecom System Engineering: Making Waves on Mars



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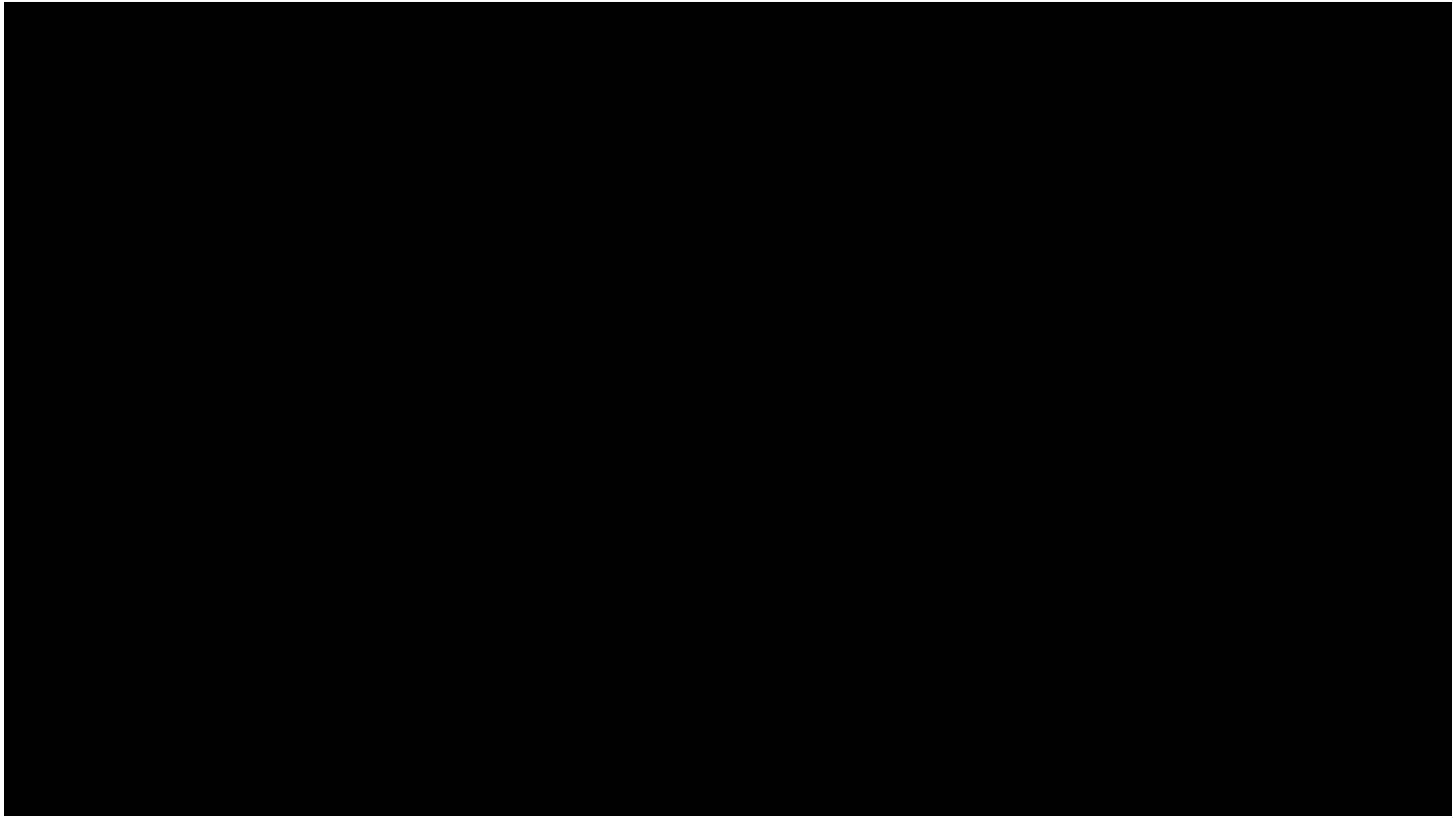
SMC-IT CubeSat Mini-Workshop

Mars Helicopter: Telecommunication Challenge



Mars Helicopter: Telecommunication Challenge

- **Nominal flights**
  - 2-3 minute duration
  - 300 meter range
  - 5 meter above ground
  - Up to one flight per sol
- **High-resolution colors images of terrain**
- **Helicopter**
  - Rotor blades: 1.2meter diameter
  - Blade speed: 1900-2800 rpm (vs 400 to 650 rpm on Earth)
  - Chassis: 14cm × 14cm × 14cm
  - Max mass: ~1.8kg
  - Average Power ~360W (solar cells)
- **Fully autonomous:**
  - Using gyroscope accelerometer, a camera, an altimeter, and on-board computer
- **Telecommunication:**
  - Transmit data from helicopter to interface box on Rover
  - During flight but primarily while landed

Mars Flight Environment

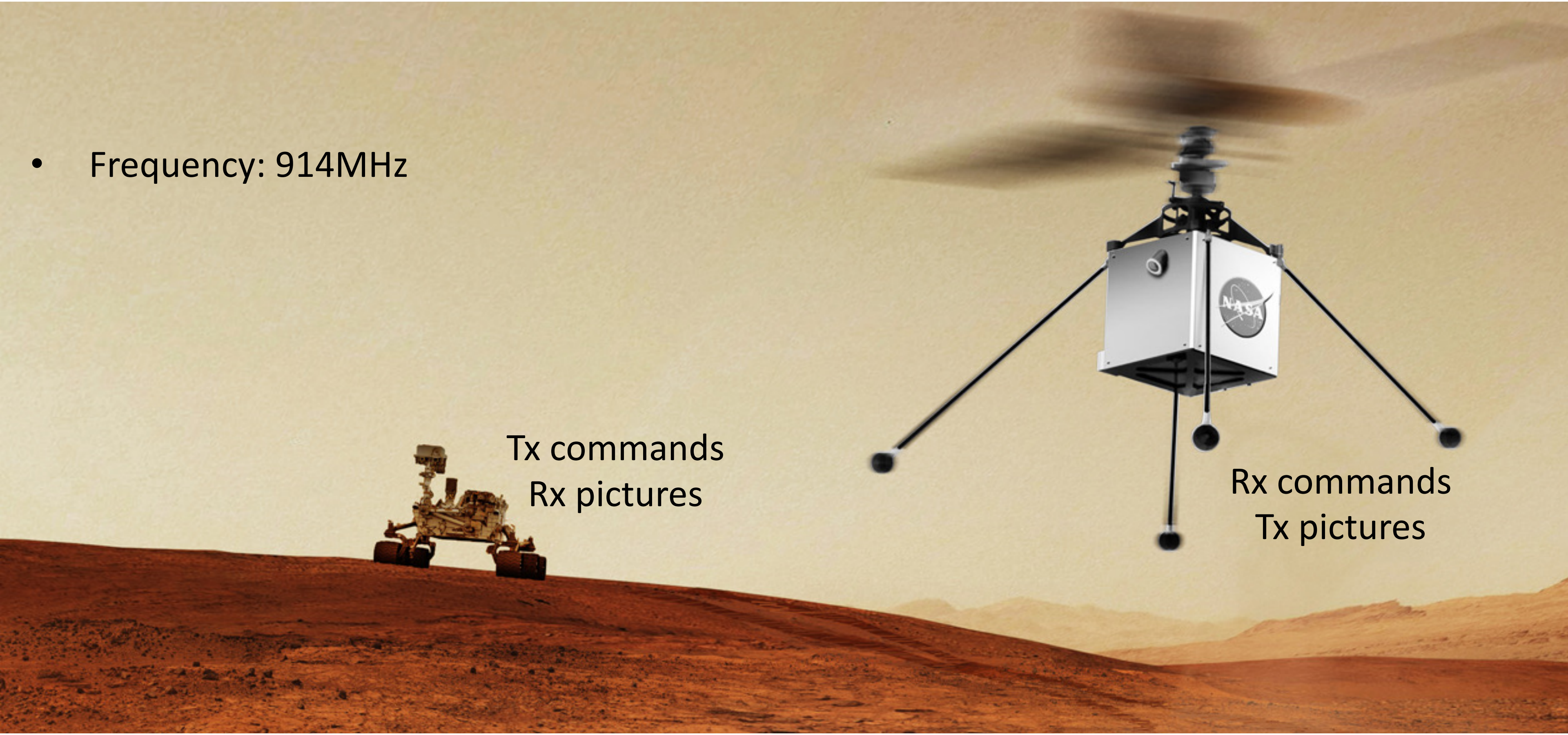
Atmospheric density: ~1% of Earth

Temperature: -90C to 25C

Gravity: ~40% of Earth

Mars Helicopter: Telecommunication Challenge

- Frequency: 914MHz



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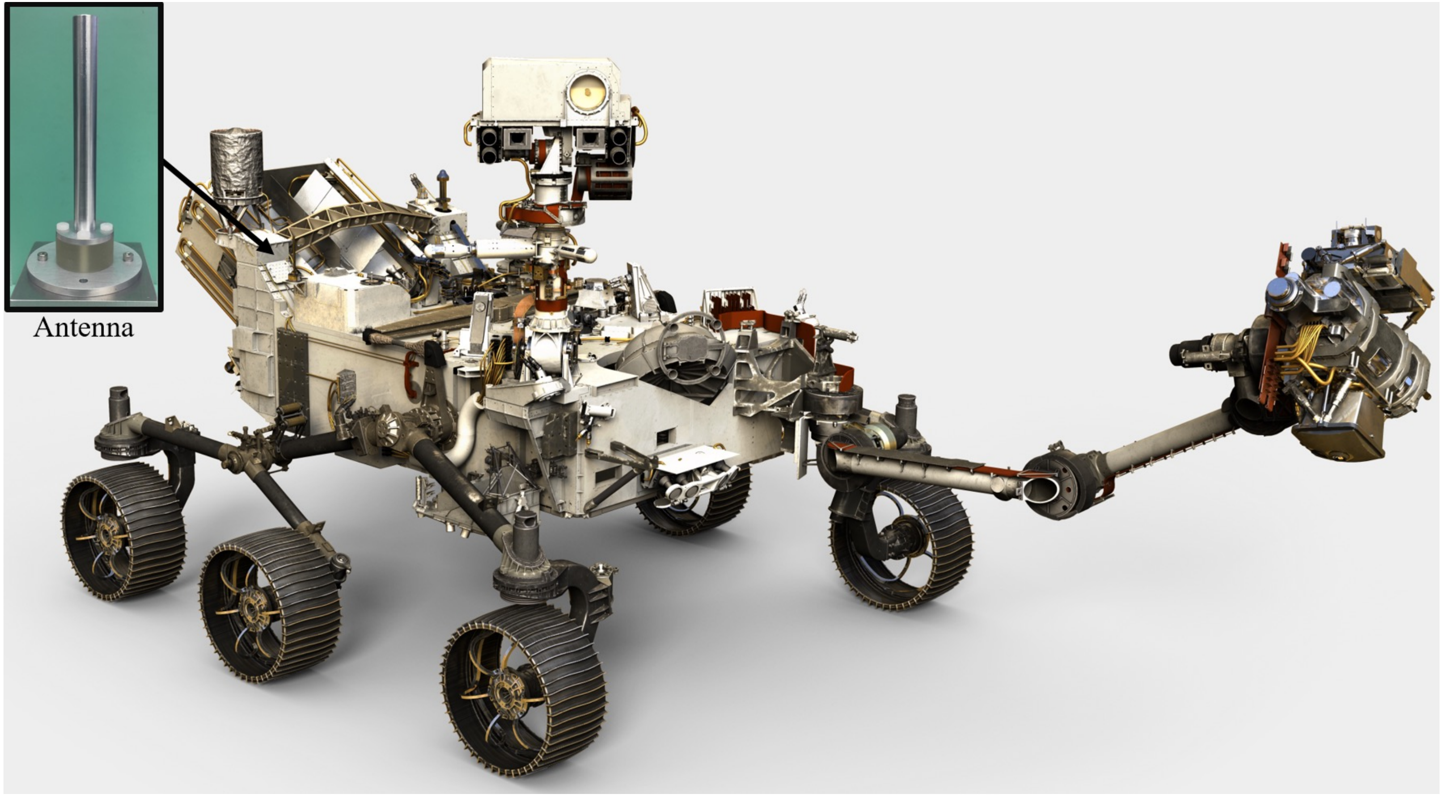

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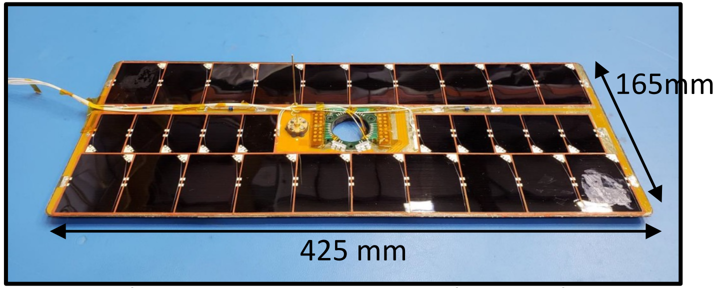
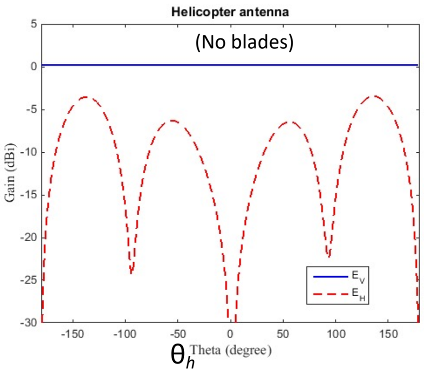
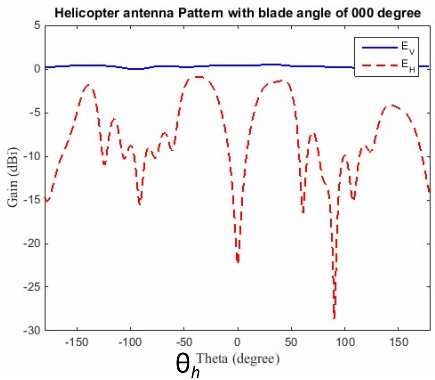
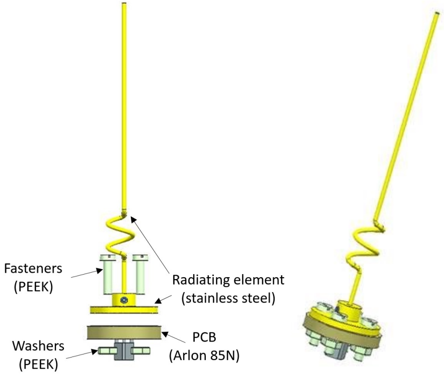


Helicopter antenna on its solar panel

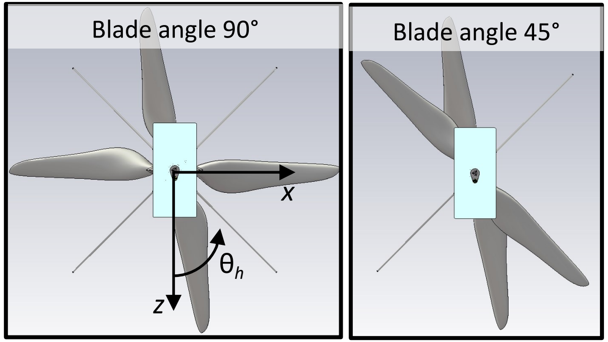
HBA radiation pattern







Antenna design



Helicopter antenna on its solar panel (includes blades)

- The blades are made of carbon fiber and are therefore reflective surfaces.
- The cross-polarization component varies as the blades rotates. This needs to be taken into account as it will affect the polarization loss.

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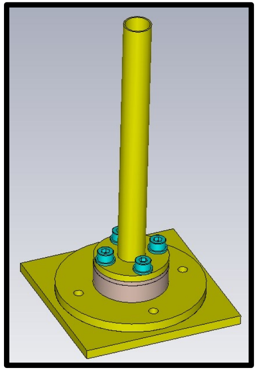
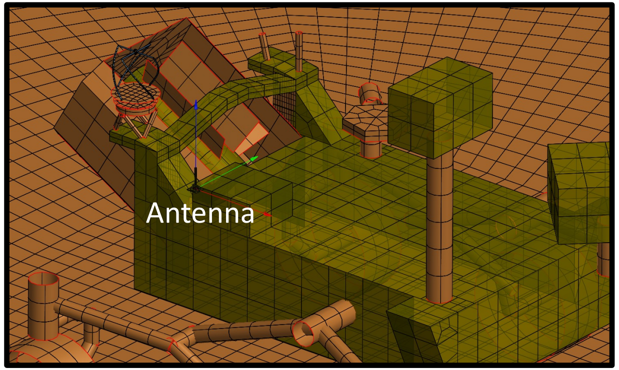
- **Antenna on Rover:**



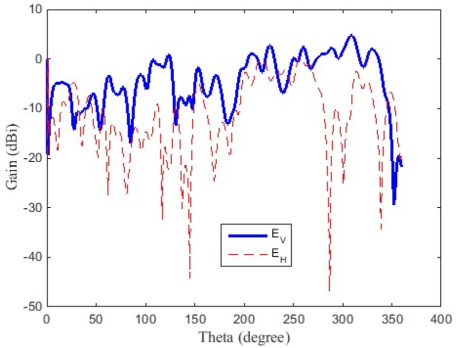
Antenna design



Antenna on M2020 Rover

Antenna testing on M2020 Rover mockup

Helicopter Base Station Antenna (HBA) radiation pattern



<u>Interpretation of results:</u>

- Shadowing effects
- Multipath (reflections)
- Suffers from a very small ground plane
- Larger ground plane and/or location would improve the result

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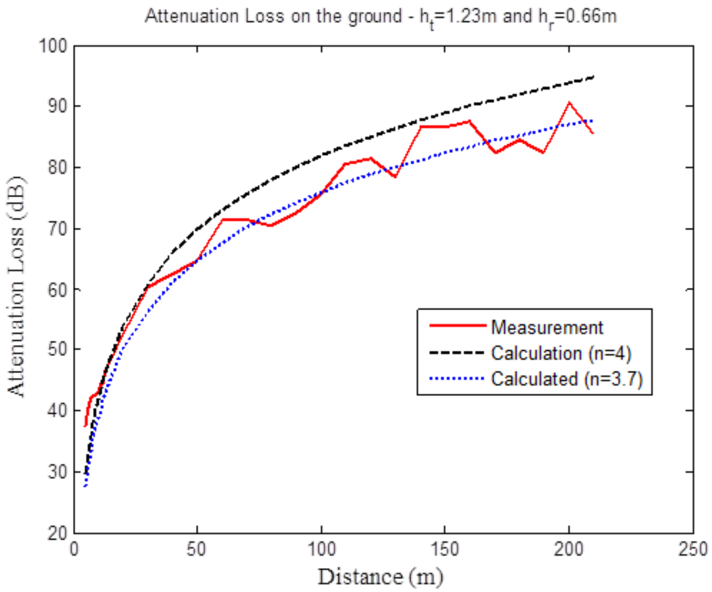
Propagation loss:

The permittivity of the Mars surface is well known but Bullington has shown that for a large distance and a flat surface, the propagation, between two antennas at heights h_t and h_r, is independent from the ground permittivity. The total path loss for a surface communications link can be calculated as: $L_{FG} \equiv -10\log_{10} \ell_{FG}(d) = -20\log_{10}(h_t h_r) + 40\log_{10} d$

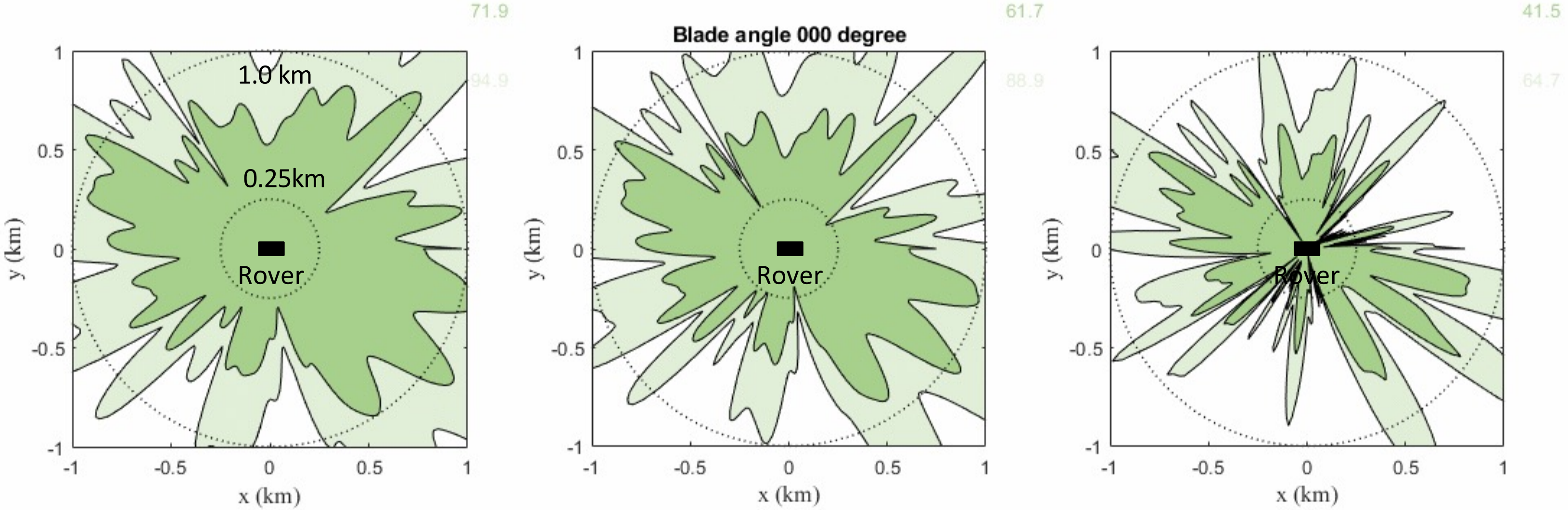
Validation:



Mars Helicopter: Telecommunication Challenge

Propagation Link while the helicopter is on the ground:

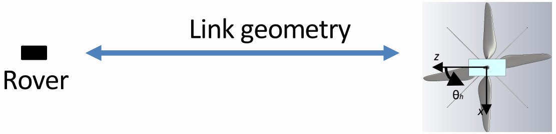
Map coverage assuming min, mean, max polarization loss with blade rotating.
The math is done for all azimuth angles around the helicopter.
These results were obtained using **Bullington** with $\boldsymbol{h_t}$**=0.48m** and h_r=1.23m.



Received power of >-99dBm ⇔ 250kbps

Received power of [-108, -99] dBm ⇔ 20kbps

No link

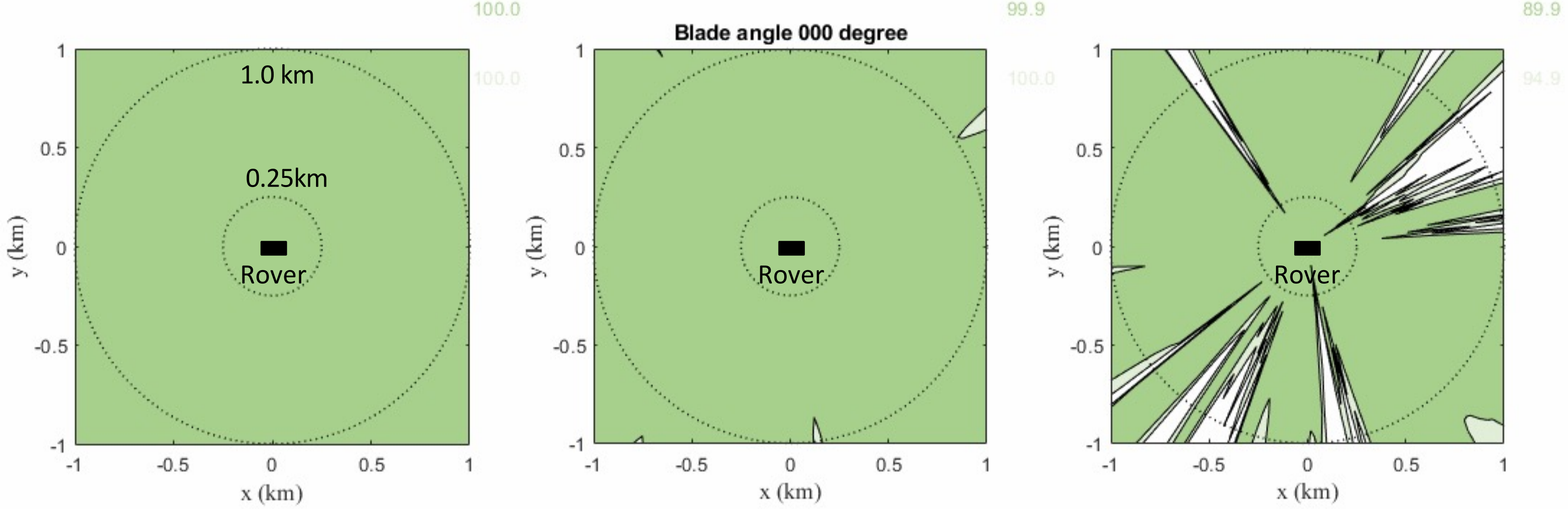


Azimuth angle θ_h = [0°-359°]

Mars Helicopter: Telecommunication Challenge

Propagation Link while the helicopter is flying:

Map coverage assuming min, mean, max polarization loss with blade rotating.
The math is done for all azimuth angles around the helicopter.
These results were obtained using **Bullington** with ***h*$_t$=0.48m** and h_r=1.23m.



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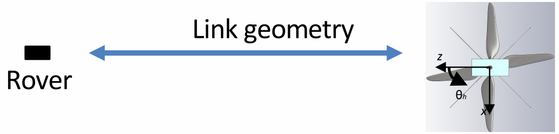

Azimuth angle θ_h = [0°-359°]

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Validation of antenna and link budget performance:

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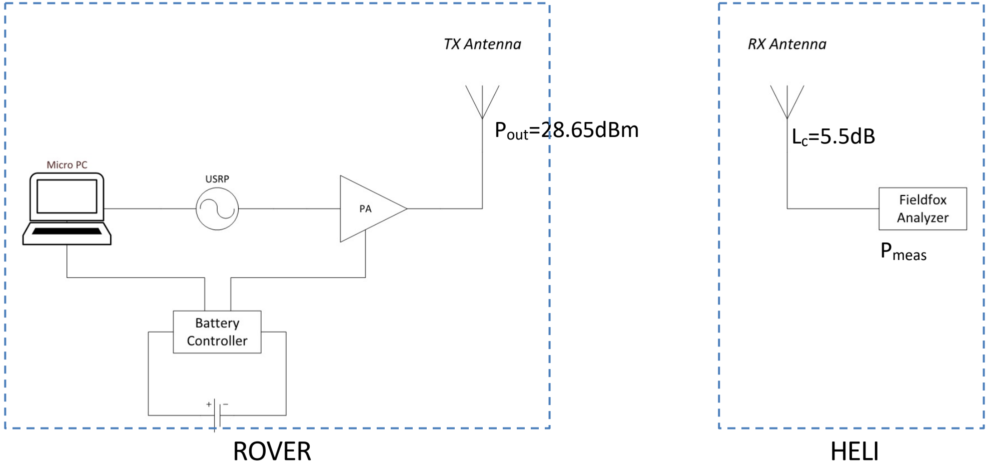
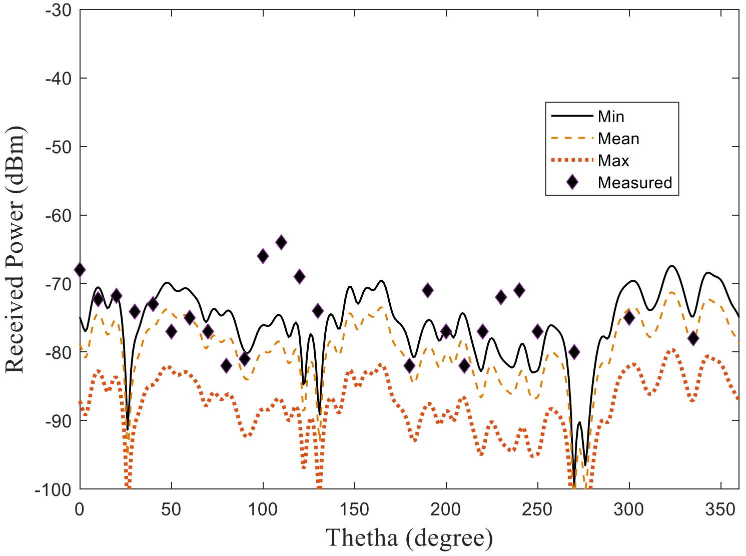
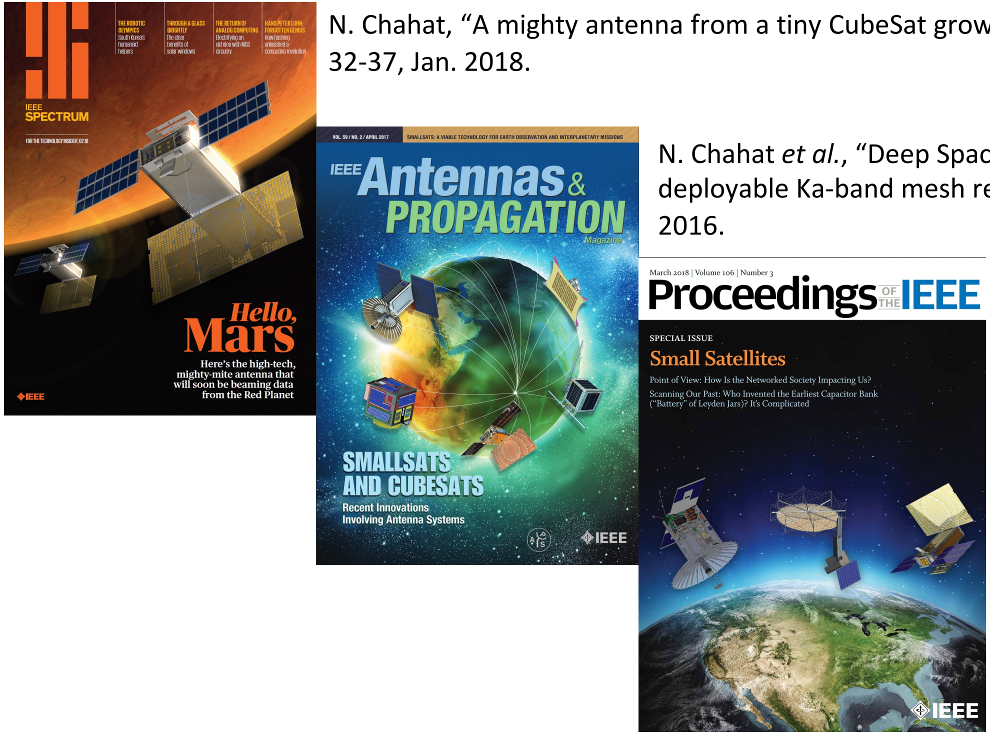
Propagation Link while the helicopter is on the ground (measured results):

Mockup of the Rover and Helicopter were used. The Rover model in simulation was modified to reflect the Mockup.
Blade alignment and helicopter pointing were aligned to be in an average case.
Distance between Rover and Helicopter: d=148m. In reality, our cables added 4.5dB (on the helicopter side), so we tested for a distance of 192m.





JPL CubeSat Antenna Technologies in IEEE



N. Chahat, "A mighty antenna from a tiny CubeSat grows," *IEEE Spectrum*, vol. 55, no. 2, pp. 32-37, Jan. 2018.

N. Chahat *et al.*, "Deep Space Network Telecommunication CubeSat Antenna: Using the deployable Ka-band mesh reflector antenna," IEEE Antenna Propag. Magazine, vol. 4, April 2016.

Book to be published in JPL Descanso Book Series – Wiley IEEE.
N. Chahat, "CubeSat antennas for Earth Science and interplanetary missions"

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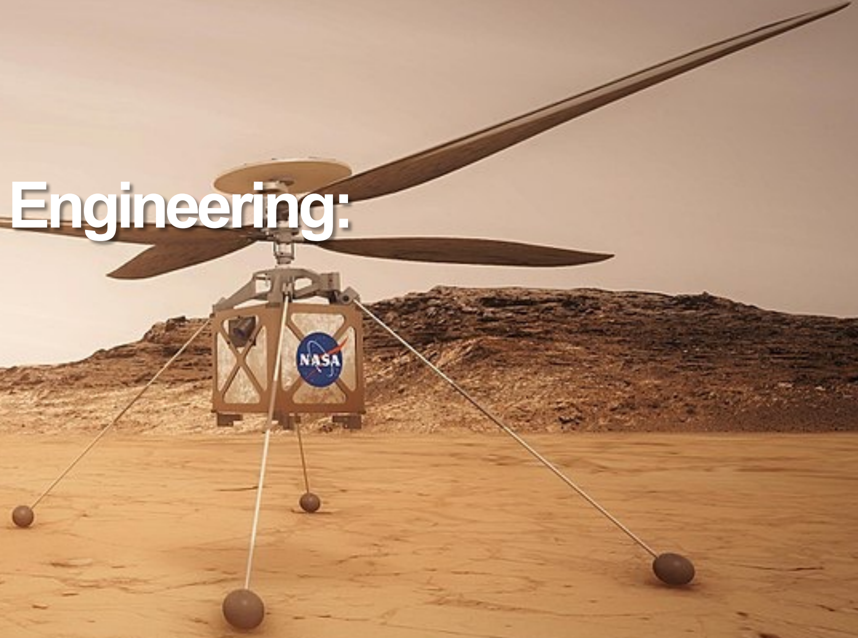

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